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Prognostics and Diagnostics Program, Tilt Demonstration

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14. ABSTRACT

Prognostics and Diagnostics provides a capability to diagnose and potentially predict end of life of components and systems. This provides the logisitican and commander valuable information on asset availability. A demonstration board was designed and built as part of the development of this capability. As an initial objective, the board was programmed to monitor tilt in two axes using an accelerometer.

15. SUBJECT TERMS

Tilt, prognostics, diagnostics

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1. Overview

1.1 Prognostics and Diagnostics Program Overview

The Prognostics and Diagnostics (P&D) program is defined as the application of appropriate sensors (data), analysis (knowledge), and reasoning (interpretation) to provide system-level health assessment, detect and isolate component degradation and impending failure, and provide appropriate alerts to the logisticians and commanders.

The goal of the program is to develop advanced health management technologies to reliably and accurately detect and quantify the status of critical components and to forecast future damage, faults, or operational degradation, to integrate into logistics decision support systems with the use of condition-based maintenance, and to give the mission commander asset availability.

This technology includes a compact sensor platform that has the capability to provide prognostics and diagnostics of systems where g-shock, temperature, humidity, vibration, and system-specific sensing are needed for system health monitoring.

1.2 P&D Demonstration Board Overview

As part of the P&D program, a series of iterative designs will be developed to provide assessment tools. As part of this series, the demonstration board, which is the first conceptual design, was built. It includes all the necessary sensors of the core unit except for the G-shock sensor. However, a non-working version of the Army Research Laboratory Micro-Electro-Mechanical Systems (MEMS) G-shock sensor is included for fit.

2. Purpose

This board provides the ability to program the microcontroller to perform functions similar to those necessary for P&D in terms of sensor data collection and simple threshold functions. It also provides the capability to measure electrical parameters such as current to allow the evaluation of various data collection processes. This will provide the initial energy usage numbers which will be used to evaluate battery life.

2.1 Development Objective

A number of capabilities are to be programmed into this demonstration board on the road map to developing a complete system. This report highlights the use of the accelerometer and microcontroller to perform tilt monitoring.

2.2 Capability Demonstration

A program to detect tilt in the positive X and/or Y direction was developed and implemented with the use of the demonstration board. The objective of the program was to detect tilt beyond a specific angle in the positive X and/or Y axis direction.

3. Implementation

3.1 Hardware Overview

A board was designed and built to represent a core P&D unit. Its purpose was to provide a bench-level circuit that functionally could be used to test and evaluate the key parts of the design, namely, the microcontroller, temperature/humidity sensor, real-time clock, accelerometer, and external flash memory. Figure 1 shows the board and figure 2 shows the schematic.

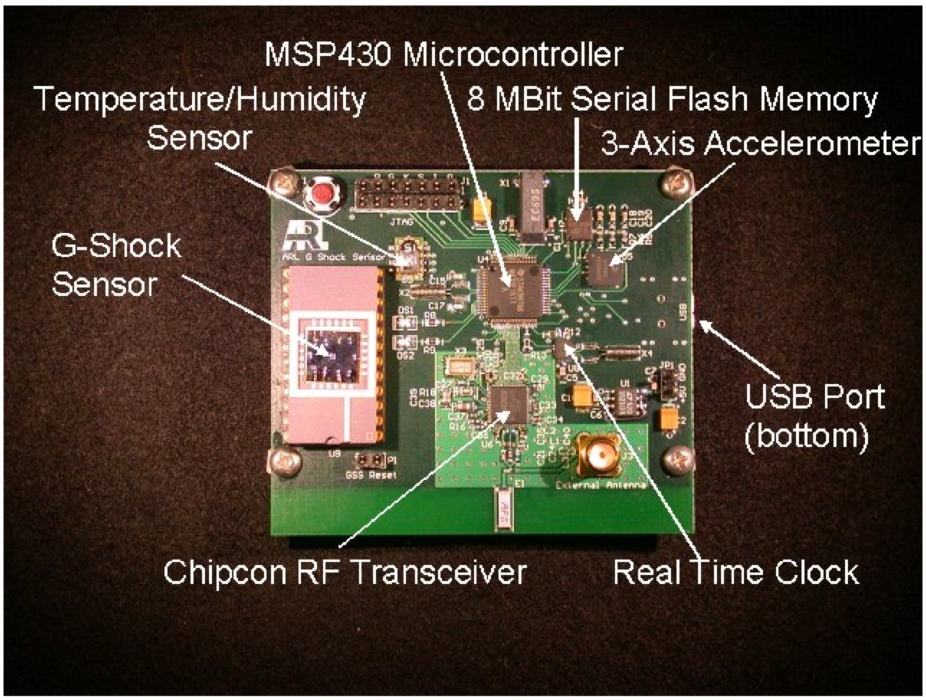

Figure 1. ARL P&D demonstration board.

The design is based on the use of as many microcontroller modules as possible. This simplifies the design and allows for testing of the microcontroller’s capabilities to determine if the internal modules provide the necessary functionality. As these determinations are made, modifications of the design to allow for additional external components such as analog-to-digital converters will be made.

The circuit also contains miscellaneous components for programming, debugging, and monitoring. These include a Joint Test Action Group (JTAG) interface for programming and debugging, two light-emitting diodes (LEDs) for monitoring, and a push button to be used as an external interrupt.

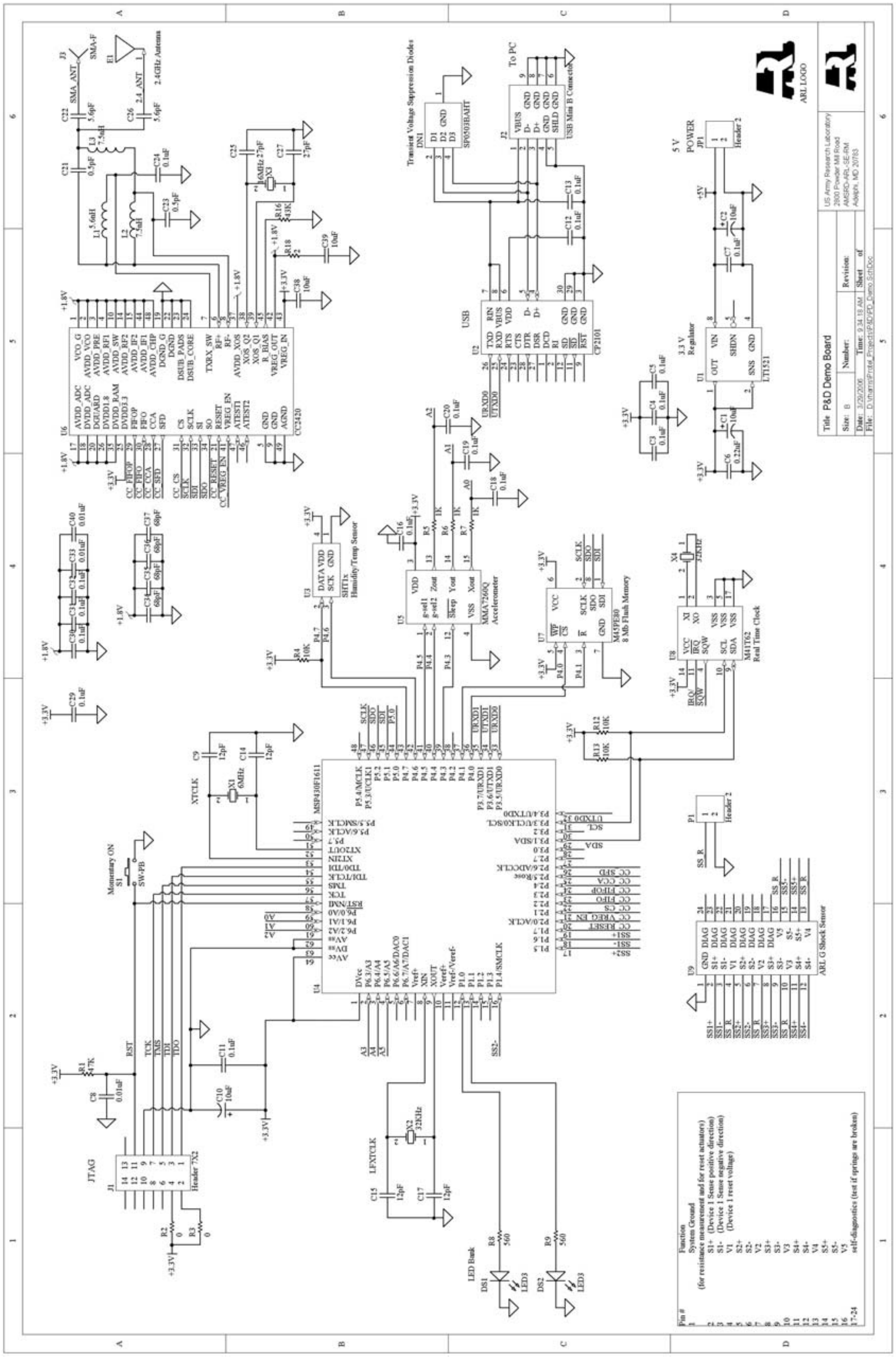

Figure 2. Prognostics and diagnostics demonstration board schematic.

Although not used for this demonstration, the circuit also contains a radio frequency (RF) transceiver and the choice of an on-board chip antenna or Sub Miniature version A (SMA) connector for external antenna.

3.2 Major Parts Used

Table 1 lists the major functional parts used in this design. In addition to the major parts, a Universal Serial Bus (USB)-to-Universal Asynchronous Receiver Transmitter (UART) bridge allows USB connectivity, a 32-KHz crystal sources the low frequency auxiliary clock input, and a 6 MHz crystal sources the high frequency clock input.

Table 1. Major functional parts.

Part	Manufacturer	Manufacturer Part Number	Part Description
Microcontroller	Texas Instruments	MSP430F1611	Ultralow-power Mixed Signal Microcontroller
Accelerometer	Freescale	MMA7260	Low power three-Axis Accelerometer
Flash Memory	STMicroelectronics	M45PE80	8-bit, serial flash memory w/Serial Peripheral Interface (SPI) interface
Real Time Clock	STMicroelectronics	M41T62	Serial access real time clock w/Alarms
Temperature/Humidity Sensor	Sensirion	SHT15	Temperature/Humidity Sensor, Fully calibrated, digital output
RF Transceiver	Chipcon	CC2420	True single-chip 2.4 GHz Institute of Electrical & Electronics Engineers (IEEE) 802.15.4/ZigBee(tm) RF transceiver with media access control (MAC) support

3.3 Software

The basic objective of this program was to use the accelerometers to determine if the board has been tilted beyond approximately 45 degrees in the positive X or Y axis (as defined by the accelerometer). With the ADC12 module of the MSP430F1611 microcontroller, a program was written to continuously loop and collect data from the X and Y axis output of the accelerometer, compare them to a fixed value that represents the approximate 45-degree tilt value, and if it is exceeded, to light the LED representing that axis. All three axes were not used since only two LEDS were available on the board. During the conversion time period, the microcontroller was placed in low power Mode 3 to save energy.

The IAR Embedded Workbench for MSP430 was used as the programming and debugging Integrated Development Environment (IDE) and C was used as the language.

Figure 3 is a flowchart of the main program and the interrupt service request (ISR) for this demonstration. Figure 4 details the accelerometer and analog to digital converter initialization.

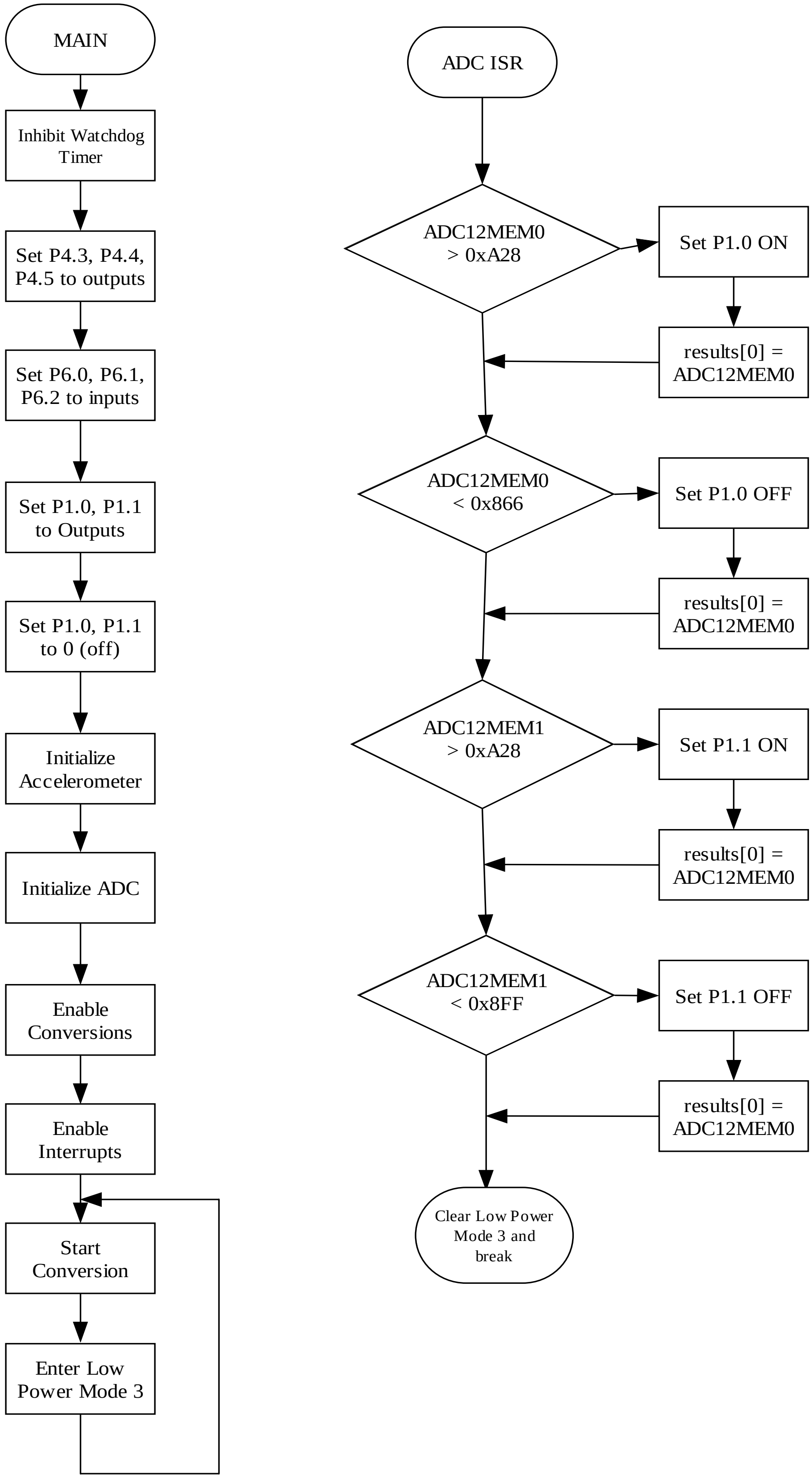

Figure 3. Flow chart of main and interrupt service request.

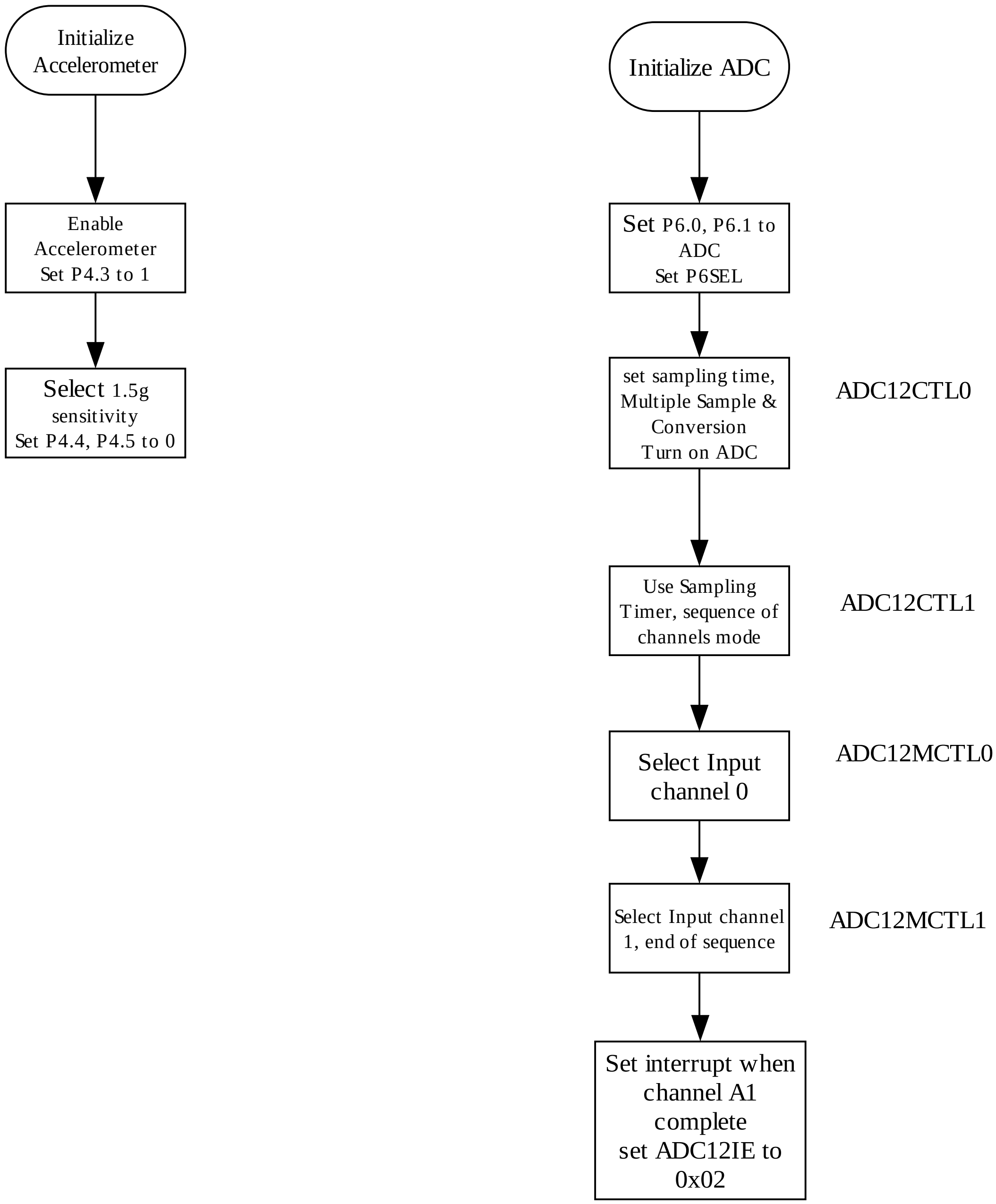

Figure 4. Flowchart of accelerometer and analog-digital converter initializations.

3.4 Source Code

```
//  Analog output of accelerometer is sent to 2 a/d inputs.
//  A single sequence of conversions is performed - one conversion each on
//  channels A0 and A1. Each conversion uses AVcc and AVss for the
//  references. The conversion results are stored in ADC12MEM0 and ADC12MEM1 and //  are
moved to 'results[]' upon completion of the sequence. The results are  //  tested against a specific
value representing an angle of tilt in the X or Y //  axis. If the test is true, an LED is lit.
//
//                  Name            Location
//                  accel sleep/      P4.3
//                  accel g-sel2      P4.4
//                  accel g-sel1      P4.5
//
//                  A0, xout          P6.0
//                  A1, yout          P6.1
//
//
//                  LED1, xth         P1.0
//                  LED2, yth         P1.1
//
//
//

#include <msp430x16x.h>
static unsigned int results[3];         // Needs to be global in this example
                                        // Otherwise, the compiler removes it
                                        // because it is not used for anything.

void main(void)
{
  WDTCTL = WDTPW + WDTHOLD;             // Stop WDT
  P4DIR |= 0x38;                        // force output DIR on P4.3, P4.4, P4.5
  P6DIR &= ~0x03;                       // force input DIR on P6.0, P6.1 using
  P1DIR |= 0x03;                        // force output DIR on P1.0, 1.1 (LEDs)
  P1OUT &= ~0x03;                       // Force P1.0-P1.1 off
  P4OUT |= 0x08;                        // force P4.3 high for accel enable
  P4OUT &= ~0x30;                       // force P4.4, P4.5 low for 1.5g sens.
  P6SEL |= 0x03;                        // P6.0, P6.1 ADC option select

ADC12CTL0 = SHT0_10 + MSC + ADC12ON;  // Set sampling time, auto 2nd, turn on   ADC12
  ADC12CTL1 = SHP + CONSEQ_1;           // Use sampling timer, single sequence
  ADC12MCTL0 = INCH_0;                  // ref+=AVcc, channel = A0
  ADC12MCTL1 = INCH_1 + EOS;            // ref+=AVcc, channel = A1, end seq.
  ADC12IE = 0x02;                       // Enable ADC12IFG.1 (interrupt when A1 done)
  ADC12CTL0 |= ENC;                     // Enable conversions
```

```
  _EINT();                          // Enable interrupts

  while(1)
  {
  ADC12CTL0 |= ADC12SC;                 // Start conversion
  _BIS_SR(LPM3_bits);                 // Enter LPM3
   }
}

// ADC12 interrupt service routine
#pragma vector=ADC_VECTOR
__interrupt void ADC12_ISR (void)
{
    if (ADC12MEM0 > 0xa28)
    {
      P1OUT |= 0x01;                   // Set P1.0 LED on (x-axis accel)
      results[0] = ADC12MEM0;          // Move results, IFG is cleared
    }
    if (ADC12MEM0 < 0x866)
    {
      P1OUT &= 0x02;                   // Set P1.0 LED off
      results[0] = ADC12MEM0;
    }
    if (ADC12MEM1 > 0xa28)
    {
      P1OUT |= 0x02;                   // Set P1.1 LED on (y-axis accel)
      results[1] = ADC12MEM1;          // Move results, IFG is cleared
    }
    if (ADC12MEM1 < 0x8FF)
    {
      P1OUT &= 0x01;                   // Set P1.1 LED off
      results[1] = ADC12MEM1;
    }
     _BIC_SR_IRQ(LPM3_bits);           // Clear LPM3, SET BREAKPOINT HERE
}
```

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